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SELECTING THE CONDITIONS FOR OBSERVING NOCTILUCENT CLOUDS FROM THE EARTH'S SURFACE AND FROM SPACE SHIPS

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SELECTING THE CONDITIONS FOR OBSERVING NOCTILUCENT CLOUDS FROM THE EARTH'S SURFACE AND FROM SPACE SHIPS

G. V. Rosenberg

ABSTRACT. The paper gives the formulas for the contrast and brightness of the cloud against the sky background. These formulas are discussed for the conditions corresponding to the site of the observer on the earth's surface, in the space ship, at the level (by day) of 60-70 km. It is stated that pearl and other stratospheric clouds situated lower than 30 km become well visible if they are observed from a space ship against the background of the early dawn. The paper shows that this method is not applicable to noctilucent cloud observations, as the contrast constitutes only fractions of a percent.

The basic criteria for selecting the conditions from observing such difficult-to-reach objects as noctilucent clouds, are naturally their brightness and their contrast against the sky's background. /30*

Besides these two criteria, other supplementary criteria should be considered, such as the size of the territory being studied and the possibility of determining the altitudinal and horizontal structure of cloud formations. Bearing these criteria in mind, let us compare the different conditions which can be realized from the earth's surface and from space ships.

When observed from the earth's surface, noctilucent clouds belong to a large diverse group of twilight phenomena. They become visible when the film of the diffused atmospheric sunlight which obscures them, dissolves, i.e., when the effective altitude H of the earth's shadow in the direction of the sighting reaches approximately 50-60 km [1]. When H becomes greater, approximately 90-100 km, the clouds become fully immersed in the earth's shadow and cease to be visible. About half of this time period their contrast C against the sky's background, as can easily be seen, amounts to the following value as a first approximation:

$$C \cong 0.2 \frac{\tau_{cloud} f_{cloud}}{\tau_{atm}(h) f_{atm}} \quad (1)$$

where h is the altitude of the cloud base; τ_{cloud} and τ_{atm} (h) are respectively the optical thickness of the clouds and atmosphere at an altitude h in the vertical direction, and f_{cloud} and f_{atm} are normalized indicatrixes of dispersion of the cloud matter and atmosphere respectively.

It is essential that the dependence of the contrast on the direction of sighting is determined here only by the factor f_{cloud} which makes the solar horizon much more favorable for the observation of the zenith or, even to a greater extent, the opposite horizon.

* Numbers in margin indicate pagination in original text.

At the same time in the red region of the spectrum the relationships of τ_{cloud}/τ_{atm} and f_{cloud}/f_{atm} are greater than in the blue region [1]. With the increase in wavelength, the contrast increases too. This is, however, achieved at the expense of a decrease in brightness.

The brightness of a cloud against the sky's background at the moment of maximum contrast is approximately equal to

$$I \cong \frac{1}{4\pi} S_0 P^m m [f_{atm} \tau_{atm}(h) + 0.2 f_{cloud} \tau_{cloud}] \qquad (2)$$

where S_0 is the solar constant for a corresponding sector of the spectrum; P is the vertical transparency of the entire thickness of the atmosphere, and m is the air mass in the direction of the observation. The I also decreases as a result of the decrease of τ_1 and an increase in the wavelength. /31

Formulas (1) and (2) remain true also for the observer in a space ship who examines the earth's twilight belt in a direction which does not drastically differ from the nadir. The only advantages of such observation are independence from weather conditions and the ability to observe larger territories during certain periods of time [2], because the observer himself and the twilight belt rapidly shift their positions in reference to the earth's surface.

In reality, the same conditions are encountered by a person observing noctilucent clouds during daylight hours against the background of space at an altitude of $L \cong$ 60-70km. Because in all the enumerated cases the observations are conducted from below or above, the main object of observation turns out to be the horizontal structure of the cloud cover. As is shown in [3], a three-dimensional spectral analysis of this structure can be a good source of information concerning the structure of the turbulent movements at corresponding altitudes.

Let us now assume that an observer situated in a space ship studying noctilucent clouds "in profile" against the background of the light aureole which fringes the part of the earth illuminated by the sun. In such a case it can be shown that the brightness of the cloudless horizon at the altitude of the noctilucent clouds is approximately equal to

$$I_{cloudless} \cong S_0 G [1 - \exp(-80 \tau_{atm})] \qquad (3)$$

where τ_{atm} is taken at the level of the layer position, and G takes into account the indicatrix of dispersion and the albedo of the lower layers of the atmosphere.

When the clouds are present, this expression takes the form of

$$I_{cloud} \cong S_0 G \left[1 - \exp\left(-80 \tau_{atm} - \frac{225}{\sqrt{\eta}} \tau_{cloud}\right)\right] \qquad (4)$$

The relative change of brightness of the horizon where the cloud layer appears is therefore equal to

$$C \cong \frac{225}{80\sqrt{\eta}} \frac{\tau_{cloud}}{\tau_{atm}} \qquad (5)$$

and if $\eta \cong$ 5 km, then $C \cong \tau_{cloud}/\tau_{atm}$, and also when observations are made in the direction of the solar horizon, this quantity becomes somewhat greater because of the indicatrix effect, which has a perceptible effect on the value of G.

It follows from (3) - (5) that, if observed from a space ship, noctilucent clouds which are illuminated by the sun (or even the moon) are bright enough and should appear sufficiently sharply against the background of the horizon. At the same time it becomes possible to distinguish the vertical structure of the cloud layer averaged along the visual line on its section of about 500-100 km in length. Also important is the possibility of simultaneous observation of a section of the horizon up to 10,000 km in length. This may be achieved, but the price is complete loss of information concerning the horizontal structure of the cloud field.

If the observer is placed not above the cloud layer but at it level, then when observing in the direction of the horizon in can be easily shown that the brightness of the observed picture will decrease substantially, but the contrast will remain practically the same as for an observer in a space ship. Therefore, such a variant does not have any advantages. Pearl and other stratospheric clouds situated at lower altitudes (approx. 30 km) become clearly visible if they are observed from a space ship against the background of an early dawn [4,5].

Nevertheless, for the observation of the noctilucent clouds such a method becomes useless, because the contrast in this case is approximately equal to $C \cong \left(\frac{225}{\sqrt{7}}\right) \tau_{cloud}$, i.e., represents a fraction of a percent only. /32

Thus, the dawn observations of the noctilucent clouds conducted from a space ship in directions close to the nadir are, in reality, duplicating the observations from the earth's surface. Being such, they at the same time increase the area of observations and make these observations free from weather obstacles. Daylight observations from a space vehicle, on the contrary, if they are conducted against the background of light aureal of the edge of the earth illuminated by the sun, can sufficiently supplement ground observations, especially in investigating the cloud layer structures and in increasing the geographical area accessible to the observer.

The intermediate variant (observations in the free atmosphere) in comparison with other variants, do not contribute anything substantially new, and, at the same time, the shadow method of observation against the background of an early dawn is generally unsuitable for inspecting noctilucent clouds.

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